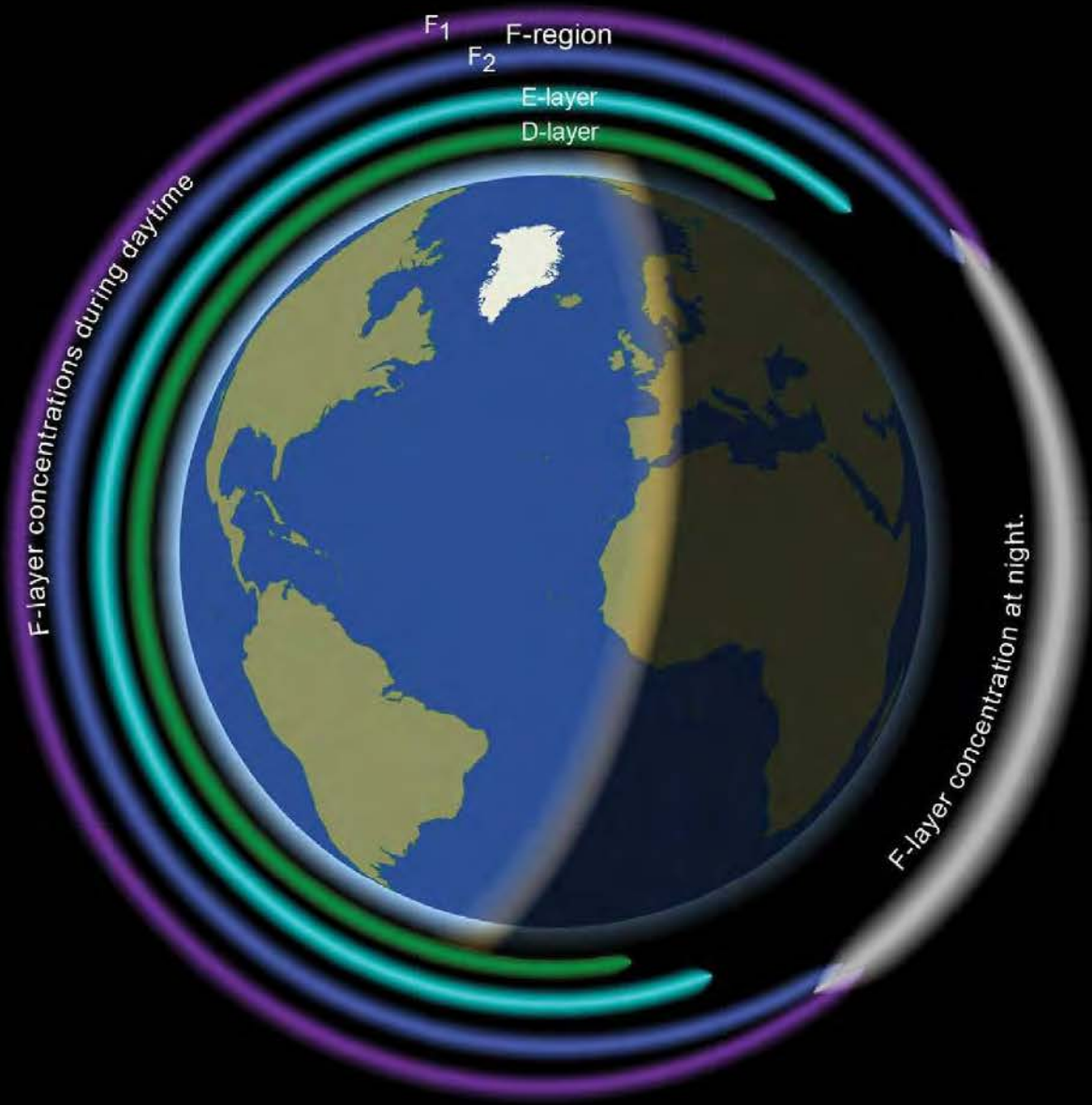
How the Ionosphere Was Confirmed

A timeline of the tools and methods used to confirm the existence and height of the ionosphere.



Robert H. Welsh, N3RW

From the beginning of the 20th century to the 1930s, physics experienced a revolution with a new understanding of quantum mechanics. Long-wave radio broadcasting grew, with new scientific studies following. Further investigation of the effects of high-energy, subatomic particle collisions with high-voltage pulse generators led to the development of new wavelength theories, such as the Austin-Cohen equation, which states that, as wavelength decreases, radio waves travel over longer distances. Given this hypothesis, the shorter wavelengths were considered useless for long-distance radio communications, and were relegated to radio amateurs, who found great success transmitting reliably over long distances.

Understanding the evolution of the methods used to study ionospheric conditions can determine success for DX chasing and shortwave listening today.

December 1901

Guglielmo Marconi received a transatlantic radio signal from Cornwall, England, to Newfoundland, Canada. From this trial, the concept of radio waves traveling over long distances was introduced.

1902

Arthur Edwin Kennelly of the US and Oliver Heaviside of England hypothesized the existence of a conducting layer in the upper reaches of Earth's atmosphere.

1909 – 1917

A.H. Taylor, a physicist and professor at the University of North Dakota, experimented with radio waves and investigated the relation between weather and received signal strength.

1912

A federal law was enacted to restrict amateurs to frequencies above 1,500 kHz — a government policy that greatly extended shortwave experimentation.

1912 – 1914

Dr. Lee de Forest and Dr. Leonard F. Miller at the Federal Telegraph Company made the first crude measurements of the Kennelly-Heaviside layer height using a spark transmitter that delivered 1,200 kW to an antenna at currents approaching 750 A. The wavelength of the transmitter was 3,260 meters (a frequency of 92 kHz). De Forest called this "apparent selective absorption" and hypothesized that the main wave was returned by a reflecting layer whose heights were 17, 27, and 37 miles above Earth. Pierce calculated the reflecting layer's height to be 192 miles.

1918 – 1923

William F.G. Swann studied the conductivity of the upper atmosphere at the University of Minnesota. Swann suggested an experiment to measure the distance of the conducting layer by measuring the time taken by wireless waves to reach that layer and return. Unfortunately, Swann's experimental procedure failed as the receiver was not fully blanked during the transmitted pulse.

1924

Albert Hoyt Taylor and his colleagues at NRL, in cooperation with John L. Reinartz, 1XAM/1QP, of the ARRL, and other radio amateurs discovered *skip distances* in which high-frequency radio waves could be transmitted to a distant receiver, while being imperceptible at many points in between.

Gregory Breit, a mathematical physicist in the Department of Terrestrial Magnetism (DTM) at the Carnegie Institution of Washington, and Merle Tuve, a PhD candidate at Johns Hopkins, investigated the conducting layer, attempting an experiment using a parabolic reflector and transmitted in the 90 MHz range to measure the height of the reflecting layer. The reflector was never built, which is fortunate in retrospect, because a 90 MHz signal would not be reflected back by the ionosphere, except under sporadic-E layer reflections. Further attempts were at much lower frequencies owing to Breit's cooperative efforts from stations in New Jersey and Massachusetts.

The best results were received from the NRL transmitter, which was one of the earliest crystal-controlled transmitters in use. Breit and Tuve used the new technique of oscillograph recording to analyze the received pulses.

The E-layer is the lower part of the ionized layer at an altitude of between 56 kilometers to 104 kilometers (35 miles to 65 miles) above the Earth's surface. The upper layer — divided into two layers (F1 and F2) — exists almost all the time, whereas the E-layer comes and goes depending on solar activity.

July 28, 1925

Breit and Tuve received the first conclusive results of ionospheric reflection at a frequency of 4.2 MHz from a 10 kW transmitter sending 200-microsecond pulses. Their results showed that the height of the reflecting layer varied from day to night. Their calculations indicated that the height ranged from 55 miles during the day, but it rose to 130 miles at night. They were not yet aware that the layers varied as a result

of solar ultraviolet and X-ray emissions, which did not excite the atmosphere when the sun was not visible. Today, users of the HF spectrum recognize that there are several layers at different heights: D at about 30 miles, E at about 60 miles, and F_1 and F_2 at heights around 180 miles.

To measure the ionosphere's height, Breit and Tuve followed the following procedure:

1) Use directional loop antennas for receiving.

2) Record the received pulses from both the sky-wave signal and ground-wave signal.

3) Apply the time difference between the sky-wave signal and the ground-wave signal.

4) From the difference, use their derived equation to measure the layer height.

5) Use a derivation of the Pythagorean theorem to compare the time for the sky wave and the ground wave to reach the receiver. From the difference in the two arrival times, Breit and Tuve calculated the height of the reflecting layer to be about 80 miles.

1945 – 1990

During the Cold War, high-frequency radio systems were still in wide use by many military organizations around the world. Using oblique sounders to provide the conditions of the ionosphere, the US could monitor radio transmissions between foreign government and military systems that were refracted from the ionosphere. One such system operated at 28 MHz, prompting the use of sporadic E-layer refraction for interception of foreign signals of interest.

The specified purpose for the oblique sounder was to receive, record, and display the echoes of the transmitted pulse. The reflected signals were used to determine sporadic-E conditions, magnetic field-aligned inequalities, disturbances in the F-region, and possible tilt of the ionosphere. Software was written to analyze the data collected by the sounder. Operational results of this system currently fall under high levels of security classification.

Current Day

Today, the most common system used is the ionosonde, a vertical incidence pulsed radar operating at a frequency range of about 1 MHz to 40 MHz. The measurement is based on the equation: $h = 0.5 \times c \times t$; where c = the speed of light, t = is the travel time of the pulse, and h is the layer height (or virtual height).

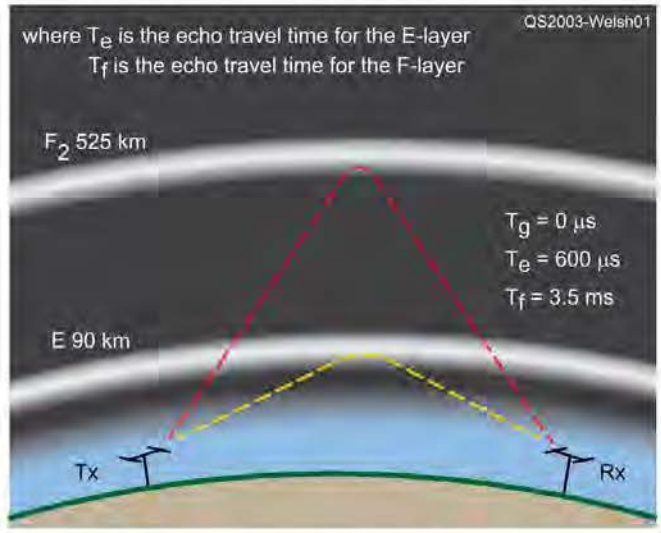

where T_e is the echo travel time for the E-layer
T_f is the echo travel time for the F-layer
QS2003-Welsh01
F_2 525 km
T_g = 0 µs
T_e = 600 µs
T_f = 3.5 ms
E 90 km
Tx
Rx

Figure 1 — A low-power ionosonde simultaneously measures seven observable parameters of reflected signals received from the ionosphere to estimate the height of the ionosphere. Here, T_e is the echo travel time for the E-layer, and T_f is the echo travel time for the F-layer.

Among other ongoing research to study the ionosphere, the University of Massachusetts Lowell Center for Atmospheric Research has developed a low-power (300 W) ionosonde (Digisonde™) which has the capability of portable operation with simultaneous measurement (see Figure 1) of seven observable parameters of reflected signals received from the ionosphere: frequency, range or height, amplitude, phase, Doppler shift and spread, angle of arrival, and wave polarization.

Impact

Commercial, military, and amateur users of the HF, VHF, and UHF regions of the electromagnetic spectrum owe much to past and present experimenters. They provide the communications community with an understanding of how signals propagate around our planet. As users of the electromagnetic spectrum, we rely on this information to better communicate by radio.

Robert H. Welsh, N3RW, is an Assistant Professor of Physics and Astronomy at Bucks County Community College in Newtown, Pennsylvania, where he is a faculty sponsor of club station KB3YRR. Robert also occasionally performs microwave radio galactic studies at the National Radio Astronomy Observatory in Green Bank, West Virginia. He was part of the Microwave Galactic Plane Survey using a dual-frequency radio telescope operating at 9.7 GHz and 14.3 GHz. Robert is an active chaser for DX entities and Islands on the Air.

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